

Planets beyond the solar system

- Review of our solar system
- Why search
- How to search
 - Eclipses
 - Motion of parent star
- Doppler Effect
- Extrasolar planet discoveries

A star is 5 parsecs away, what is its parallax?

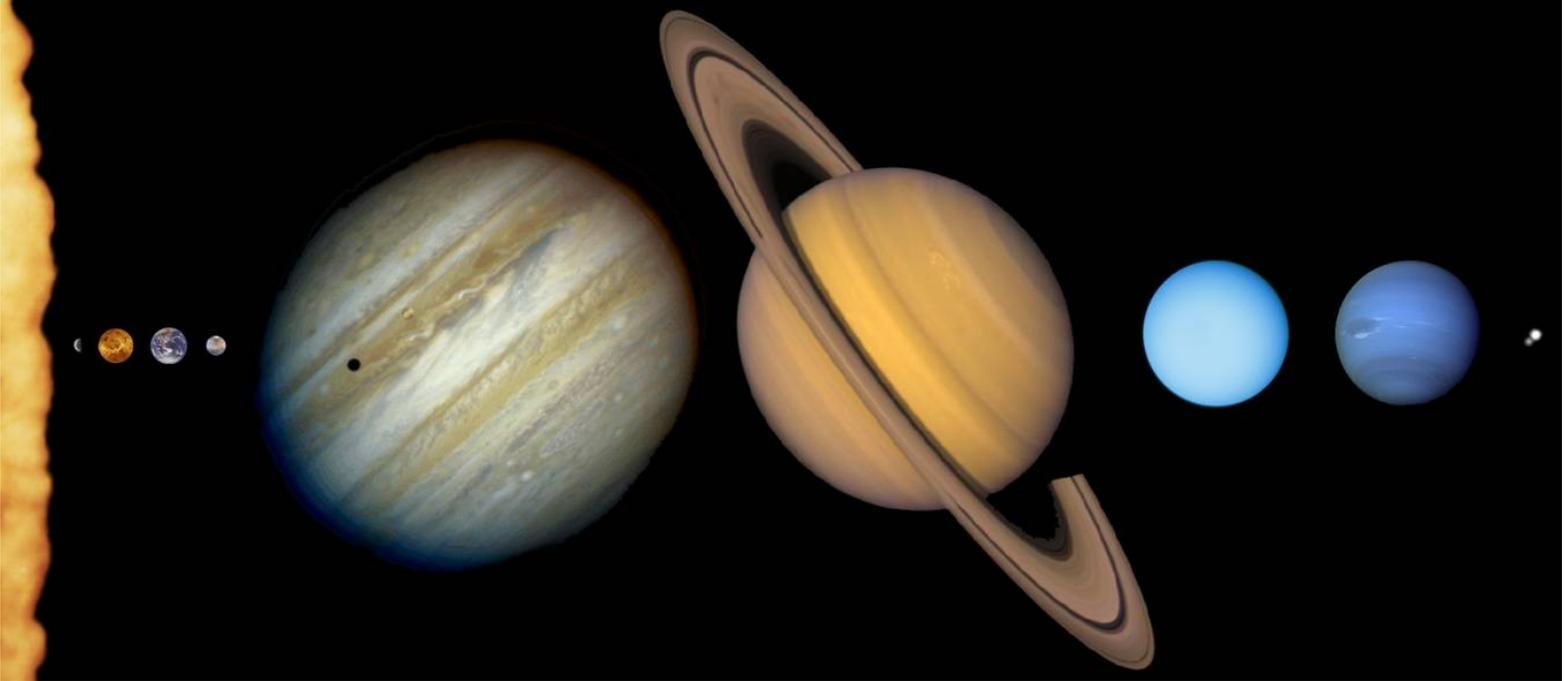
A) 0.1"

B) 0.2"

C) 0.5"

D) 1"

Our solar system



- Inner planets are small, rocky
- Outer planets are gas giants
- Mercury is closest to Sun at 36 million miles

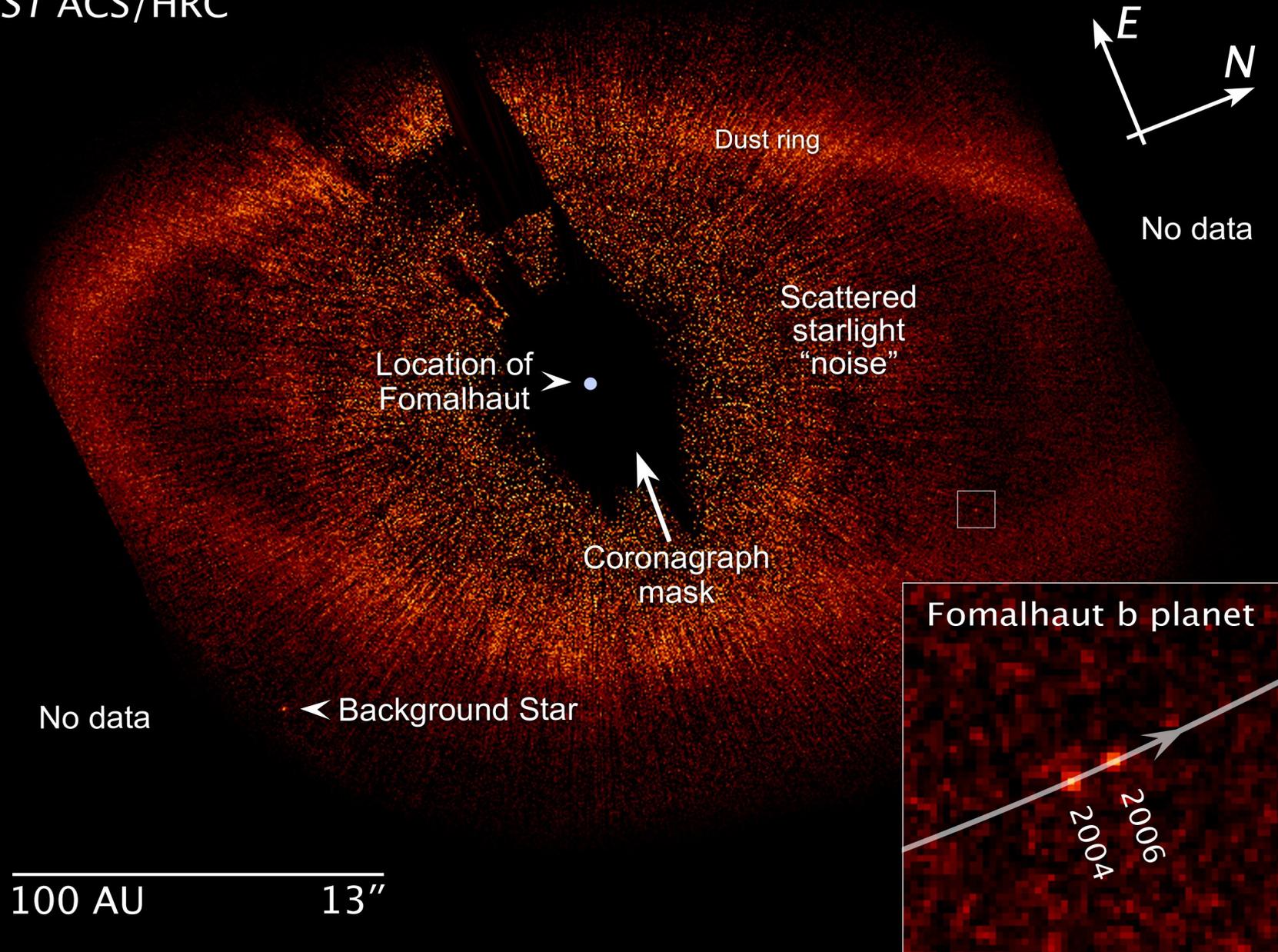
Why search for extra solar planets?

- Search for life.
- Understand how our solar system formed.

How to search for planets

- Take pictures, see if there are planets.
- Stars are much brighter than planet
 - Makes it hard to see the planets due to the glare of the star.
- Planets are close to their parent star
 - Makes it hard to resolve the planet from the star
- Taking pictures succeeded only last last year...

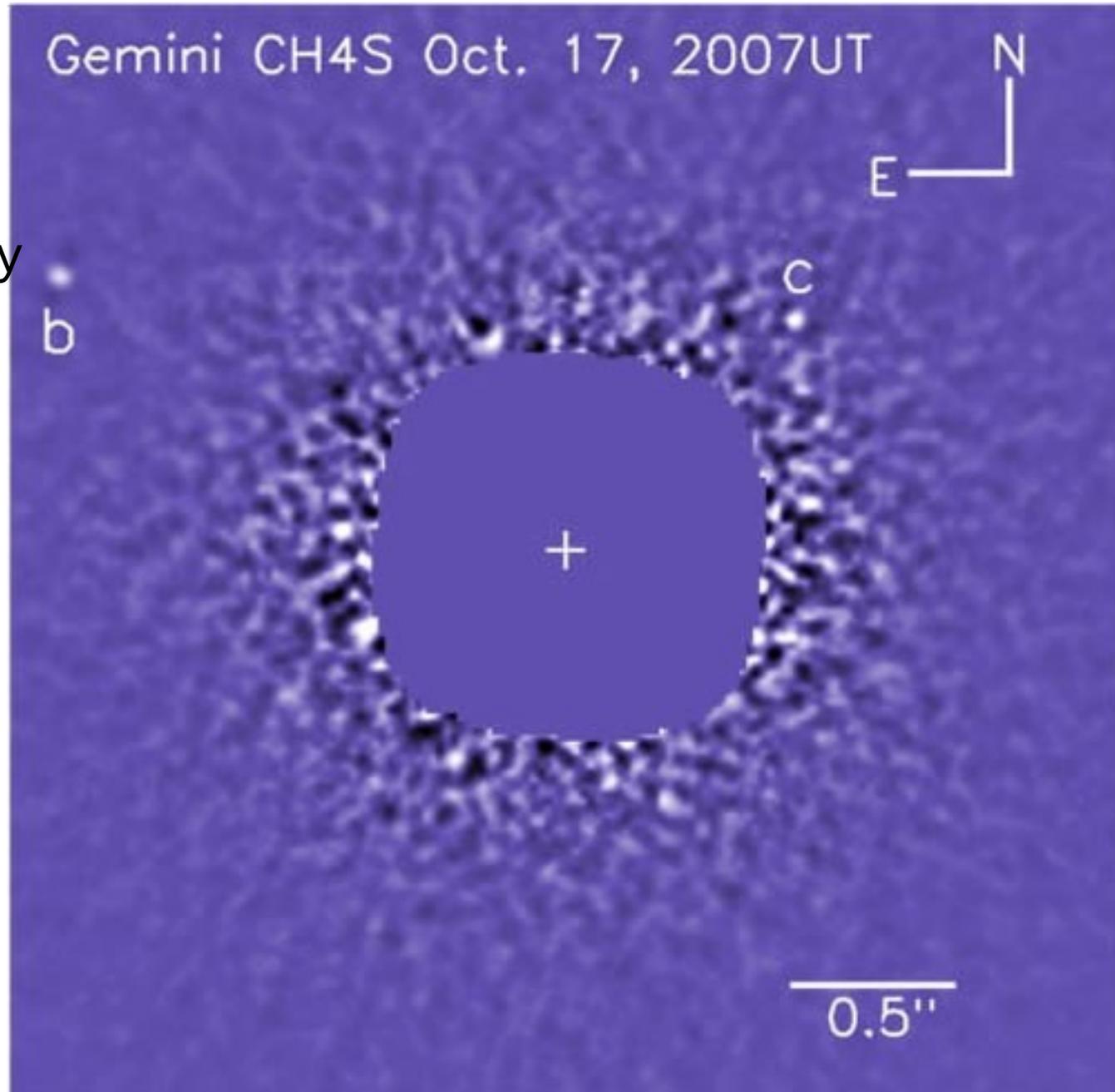
Fomalhaut
HST ACS/HRC



HR 8799

150 light years away

- Image in infrared
- Planets only 60 millions old
- Still glowing with heat from their formation



How to search for planets

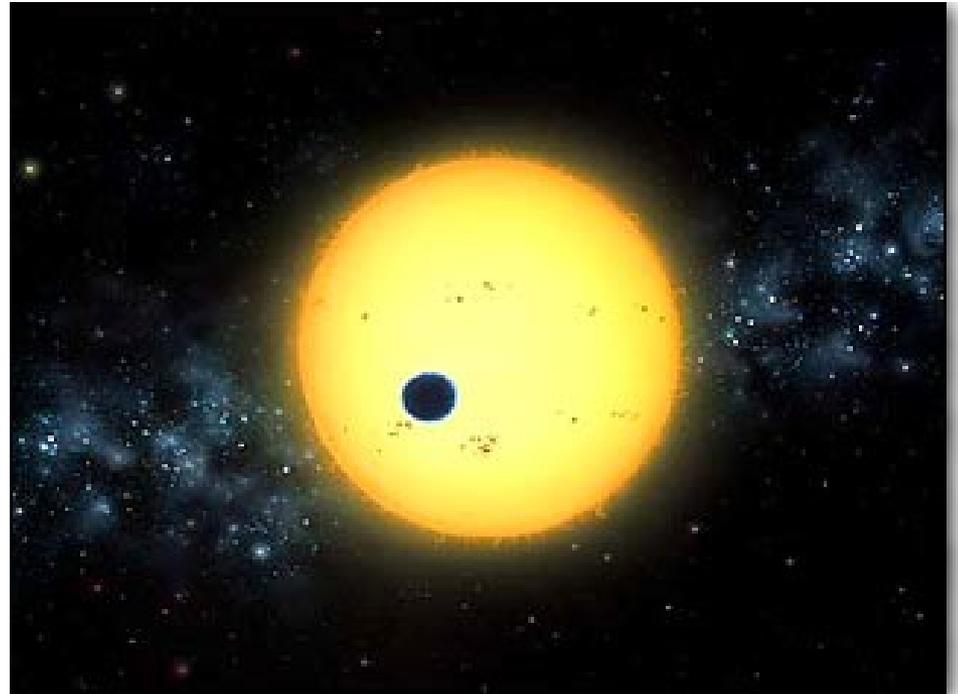
- Most planets are too close to their parent star and too dim compared to their parent star to be seen in direct images.
- We need to look for effects of the planet on the light coming from the parent star.

How does a planet affect light coming from its parent star?

- The planet can block the light - an eclipse
- The planet can cause the star to move

Extrasolar eclipses

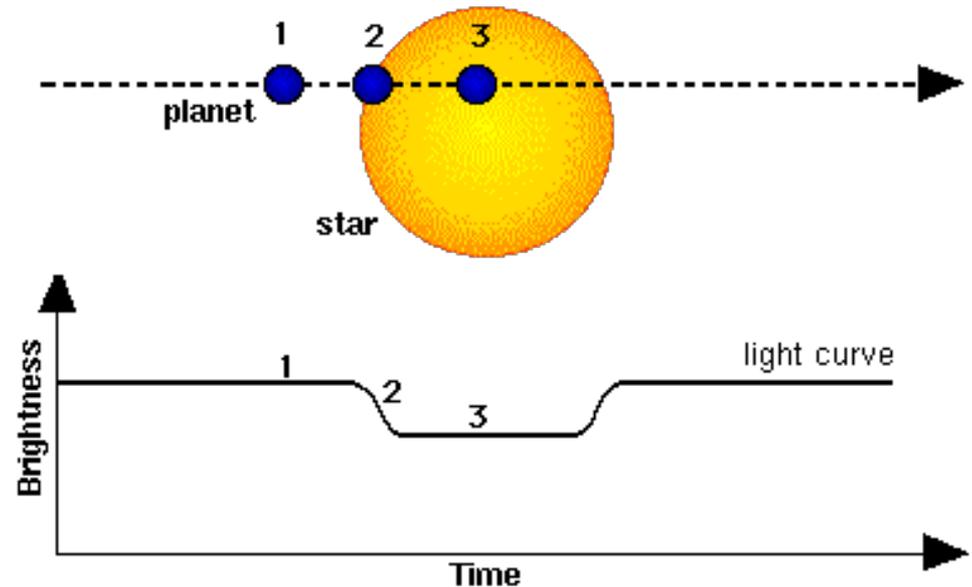
In the same way that the moon blocks the sun and causes eclipses on Earth, a planet orbiting another star can block part of the light from that star and cause an eclipse seen from Earth.



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Extrasolar eclipses

However, we can't yet make images of the disks of other stars, so all we can measure is the total light from the star. Since the planet is much smaller than the stars, the total light is reduced only by a few percent, even less for Earth-like planets.



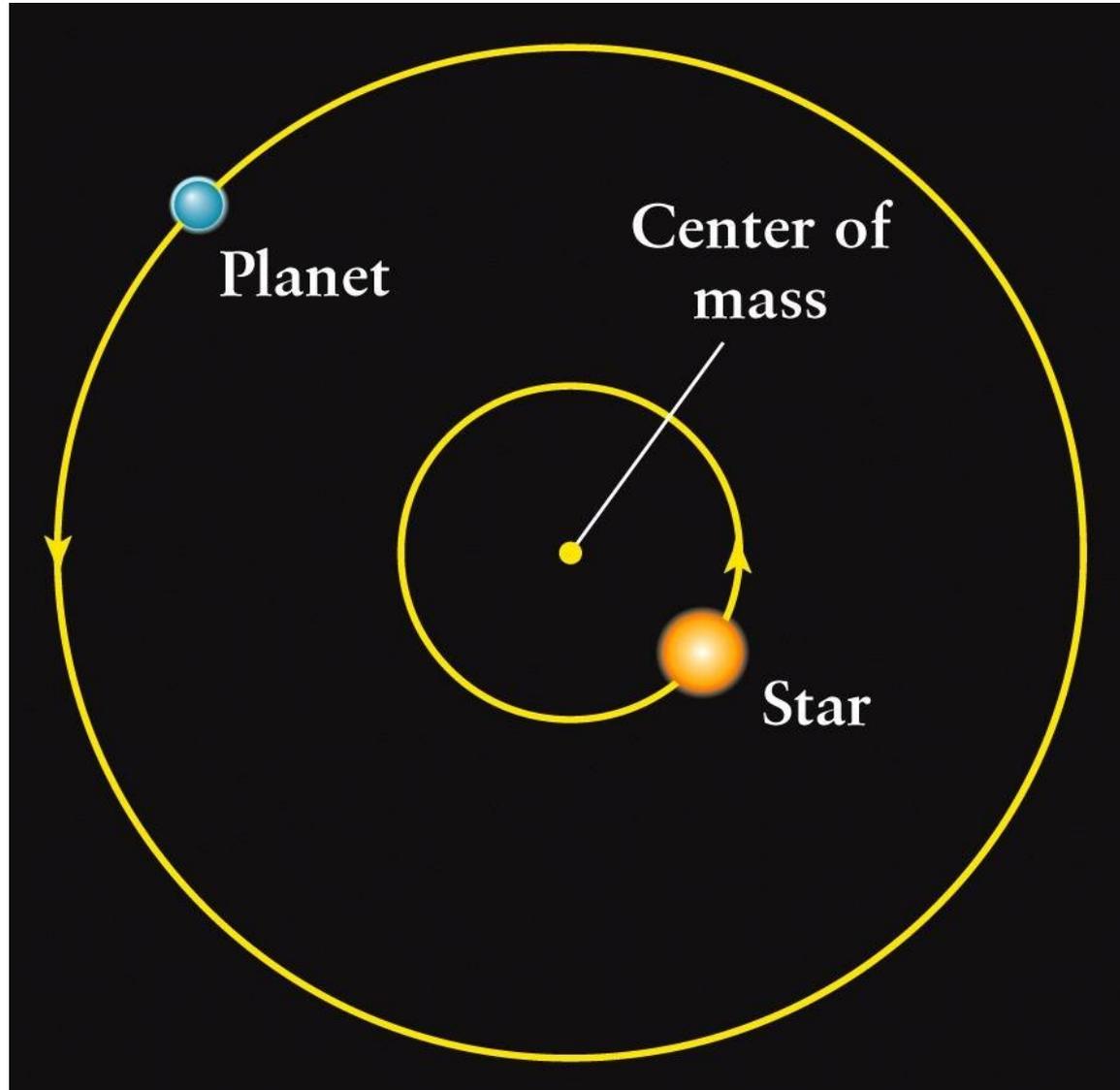
Extrasolar eclipses

- Eclipses have a more serious problem in that we cannot see an eclipse from Earth if the orbit of the planet is tilted relative to our line of sight.
- Only a few percent of planets are expected to have orbits at just the right angle so that we can see eclipses.
- Need a more general way to search.

How does a planet affect its parent star?

- A) The planet causes the star to precess due to Newton's law of rotation.
- B) The planet causes the star to move slightly due to Newton's law of action and reaction.
- C) The planet causes the star to exert a gravitational force according to Newton's law of gravitation.
- D) The planet causes the star to remain at rest due to Newton's law of inertia.

Mutual orbits of planet and star

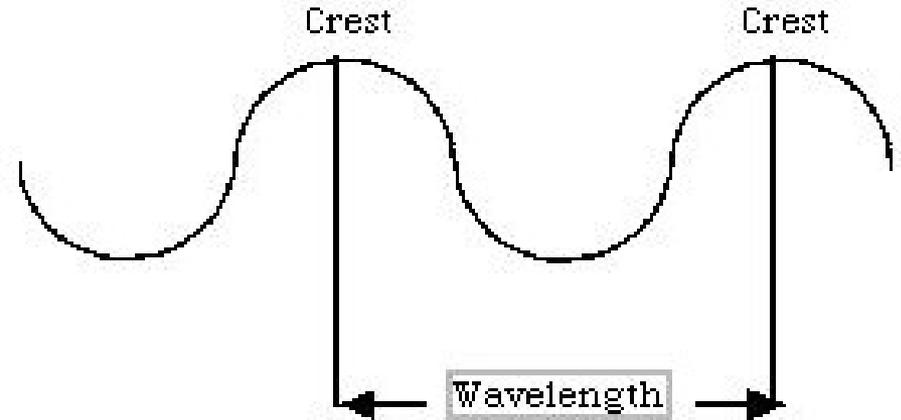


So, the planet causes its parent star to move.

We can see the light from the star, but how can we detect motion of the star?

We can use the “Doppler effect”...

Waves

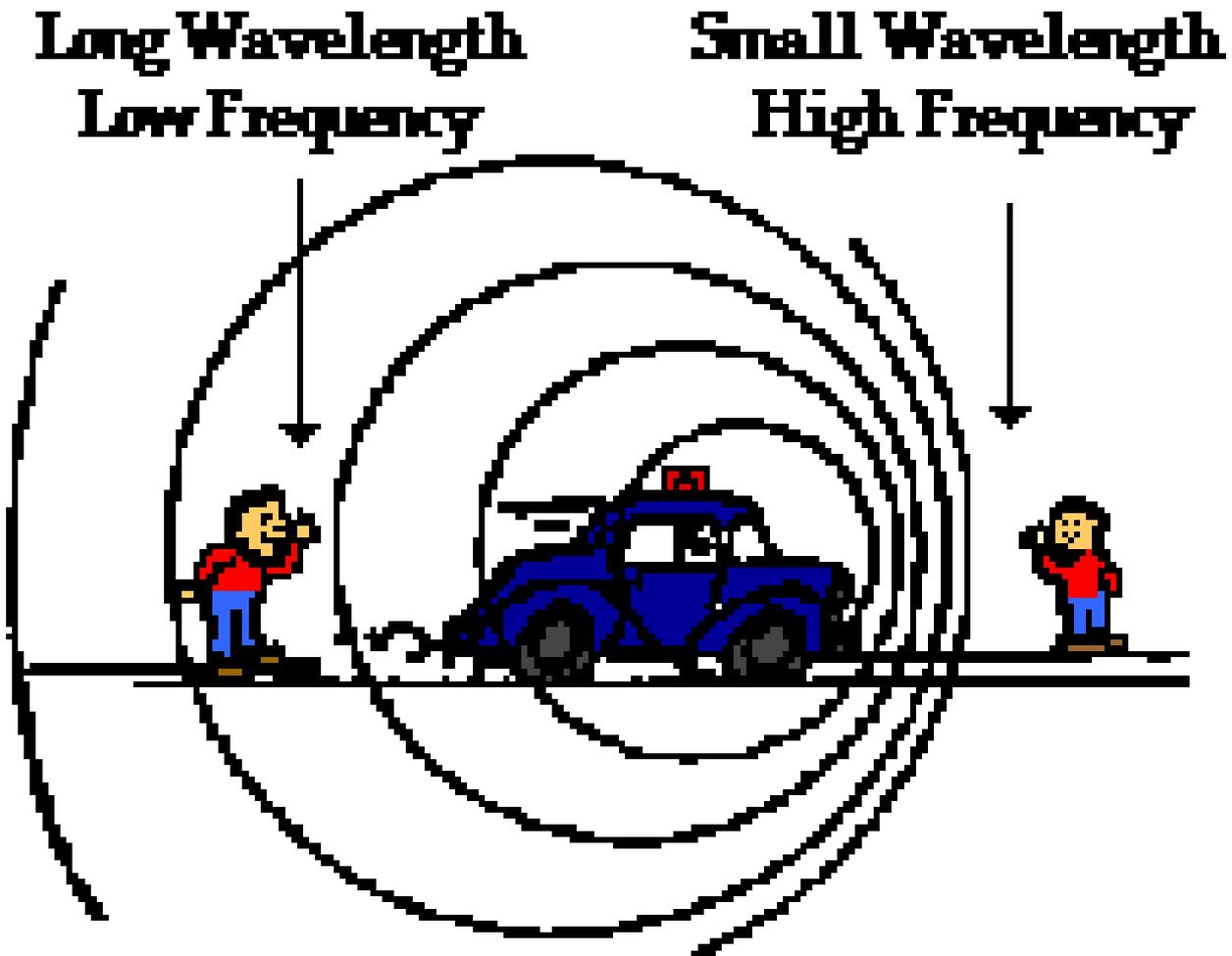


- Sounds waves have crests and troughs
- The pitch or tone of a sound is determined by how fast those crests and troughs arrive at your ear.
- Since sound travels at constant speed, how fast the crests and troughs arrive at your ear is inversely proportional to the distance between successive crests – the wavelength.

Doppler effect

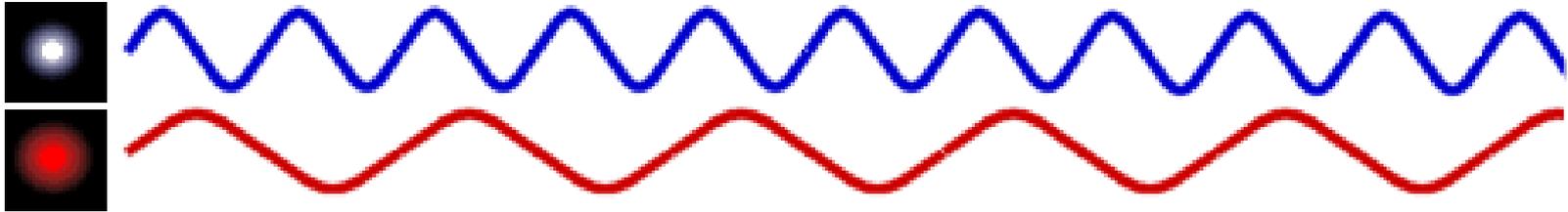
- The buzzer makes a constant pitch
- When the buzzer is moving towards you, the waves get bunched up – the pitch sounds higher.
- When the buzzer is moving away, the waves get spread out – the pitch sounds lower.

Doppler effect



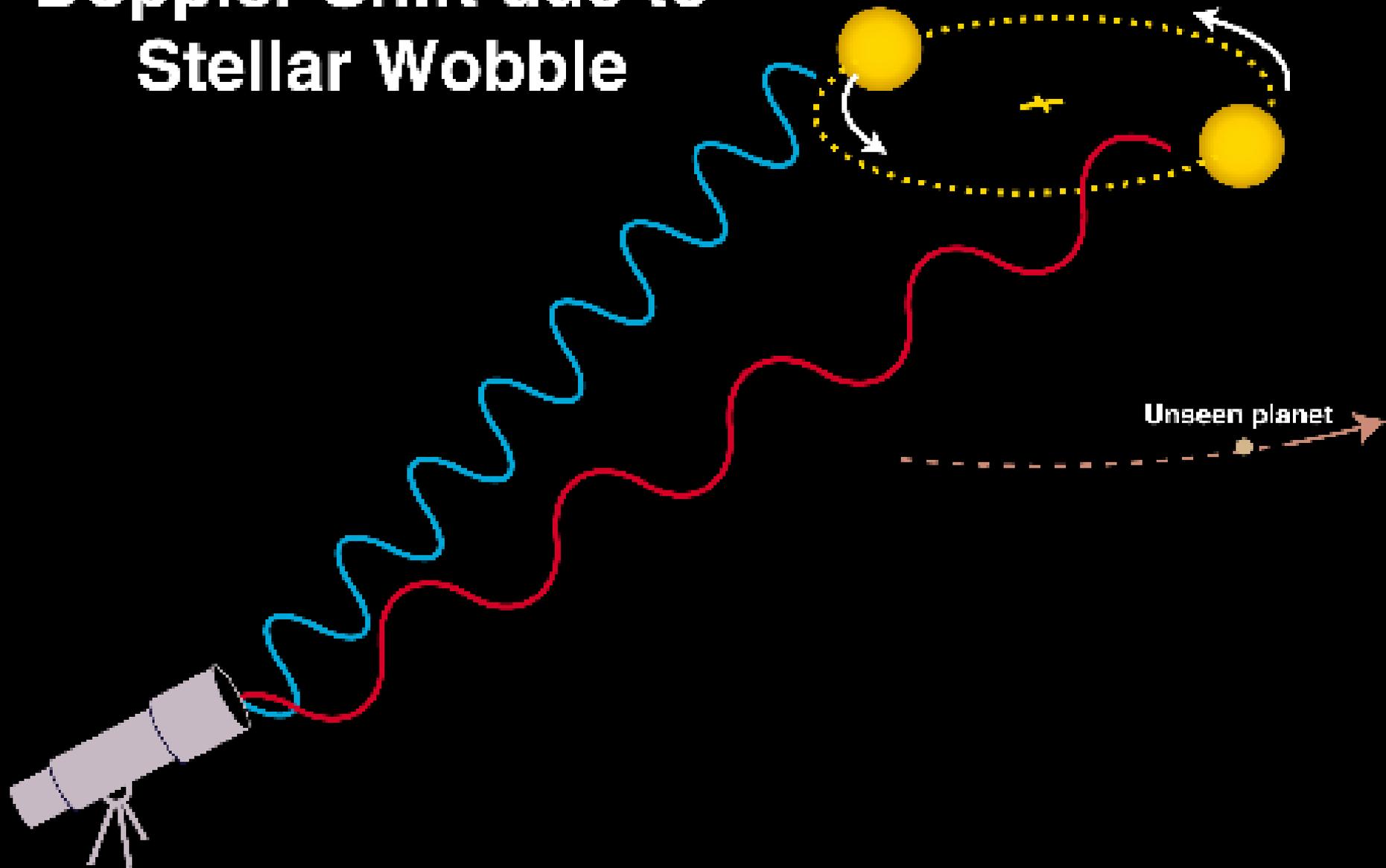
The Doppler Effect for a moving sound source

Doppler effect



- The same effect works for light waves as well as sound waves
- For light waves, blue means shorter wavelengths and red means longer wavelengths

Doppler Shift due to Stellar Wobble



The Doppler effect (for sound) is caused by

- A) a German guy named Doppler
- B) a change in the speed of sound for moving objects
- C) motion of a source between emission of successive sound waves
- D) compression of sound waves due to motion of air

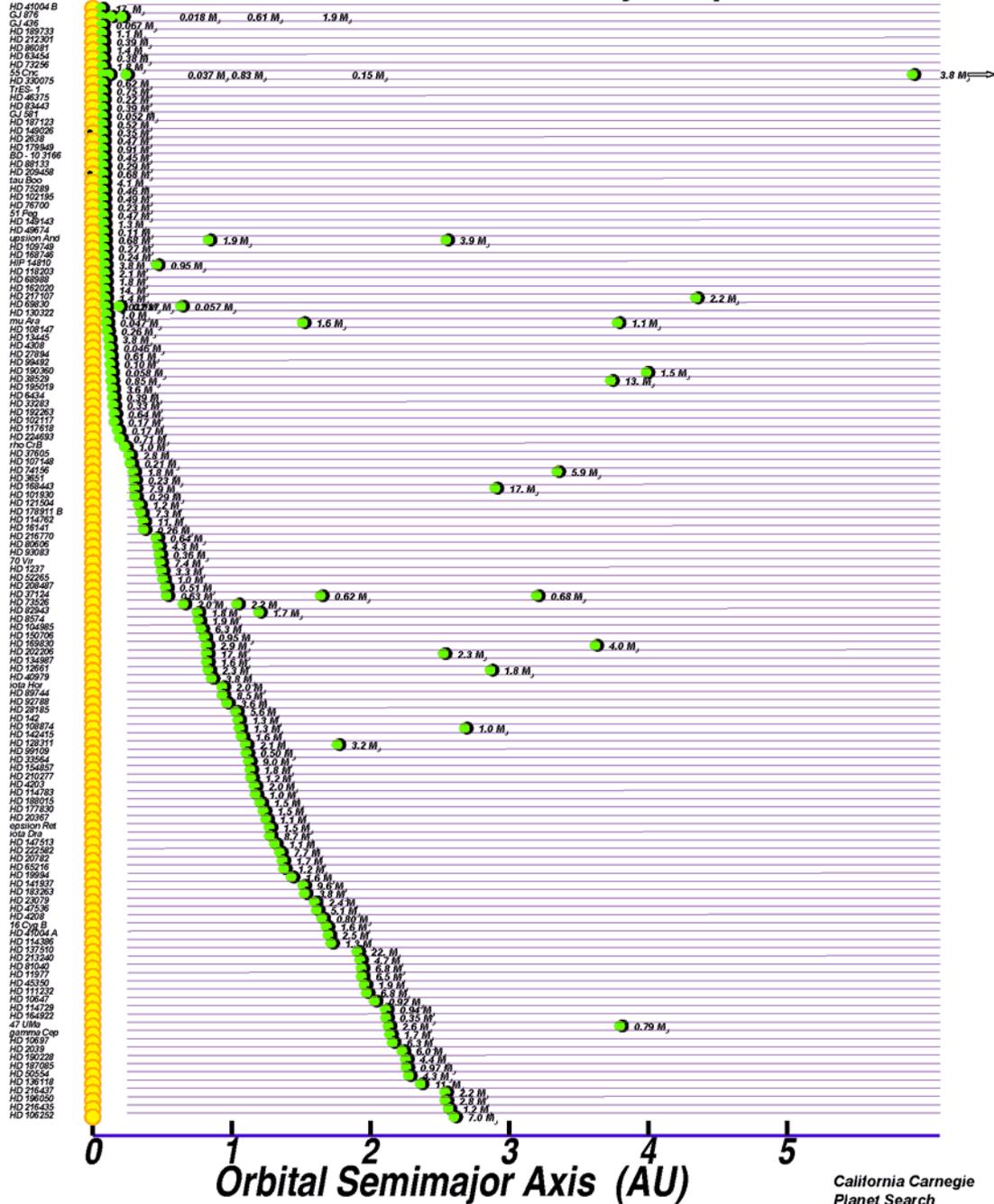
Extrasolar planets – 51 Peg

- First extrasolar planet discovered
- Half the mass of Jupiter
- Orbits its star in 4.2 days, compared to 4330 days for Jupiter.
- Is only 5 million miles from its sun, 1/8 the distance that Mercury is from our Sun.
- Destroyed existing theories of planet formation based on our solar system.

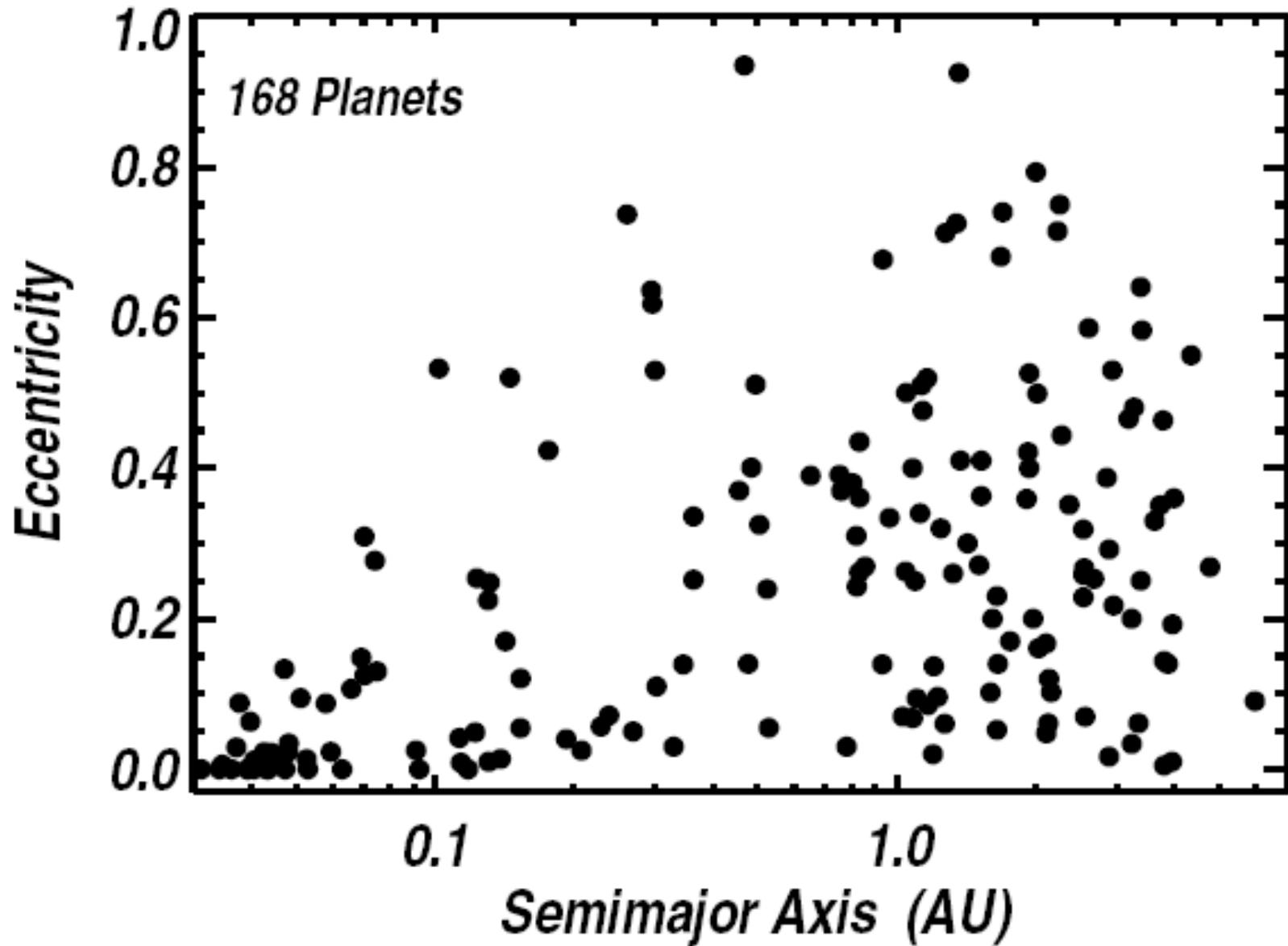
Extrasolar planets to date

- First extrasolar planet was discovered around a neutron star in 1991
- First extrasolar planet orbiting a normal star was found in 1995 by Michel Mayor and Didier Queloz of the Geneva Observatory in Switzerland orbiting the star 51 Pegasi
- 336 candidate planets have been discovered orbiting 286 different stars (as of February 1, 2009), see <http://exoplanet.eu>

The 178 Known Nearby Exoplanets



Orbits of extrasolar planets



Why is it easier to use Doppler shifts to discover heavy planets in close orbits than light planets in far orbits?

- A) The light planets produce a larger force on the star.
- B) The heavy planets produce a larger force on the star.
- C) The heavy planets reflect more light.
- D) Doppler was a heavy guy.

System “most like ours”

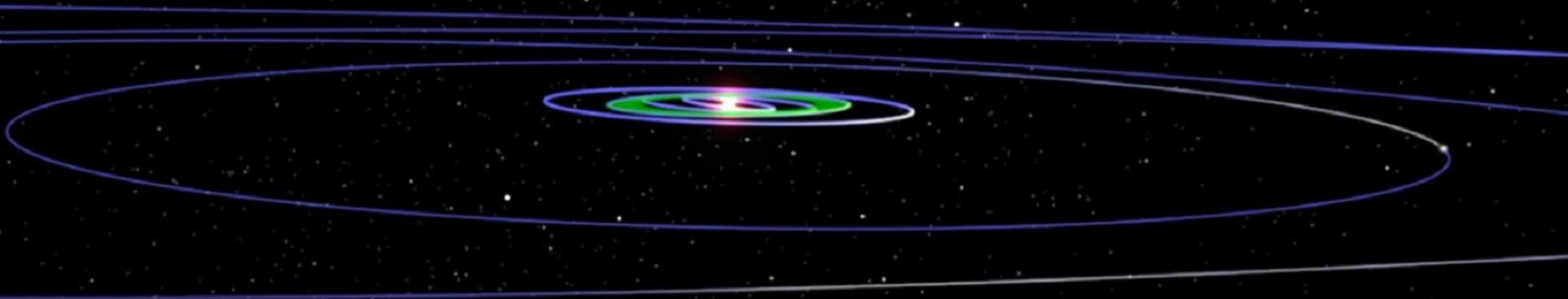
55 Cancri

- Star 60% as bright as the Sun and only 5% less massive than the Sun.
- Five planets
- Outermost known planet has an orbit similar to that of Jupiter, but is 4 times the mass of Jupiter.
- Inner 3 planets all lie within the orbit of Mercury – one is about the mass of Jupiter.
- Other planet has half the mass of Saturn, orbit a little less than one A.U.

55 Cancri

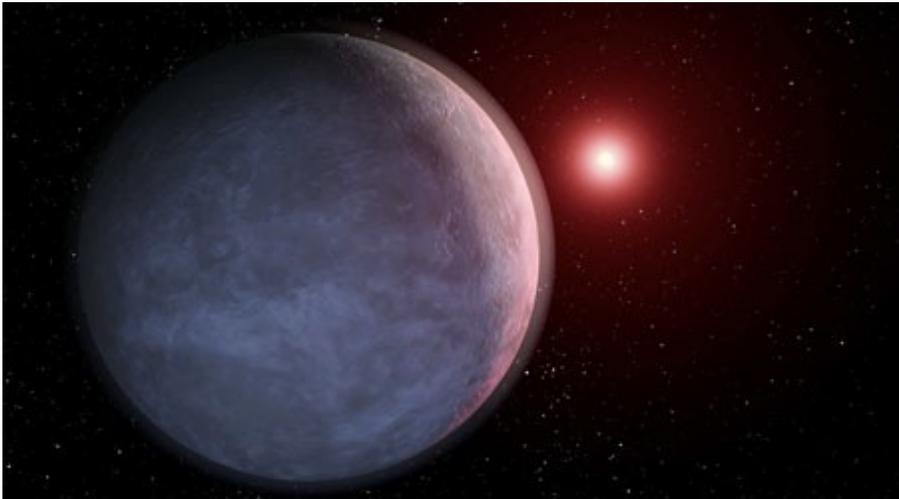


55 Cancri Planetary System



Our Solar System

Smallest extrasolar planet



- MDA-2007-BLG-192L
- 3 times Earth mass
- Star is a red or brown dwarf
- Thought to be like Neptune
- Very cold because of dim star

Extrasolar planets

- Most discovered so far are Jupiter-sized.
- Most are also close in to their star.
- This is because massive planets close to their parent star cause the star to move more and are easier to find, especially if observing for a limited time.
- Many have non-circular orbits.
- Probably rocky planets have been discovered only in the past few years.
- Estimated there are at least 20 billion planetary systems in our Galaxy.

Review Questions

- How does a planet affect the motion of its parent star?
- What happens to the wavelength of sound or light emitting from an object moving away from you?
- Are extrasolar solar systems similar to our own?